Australian
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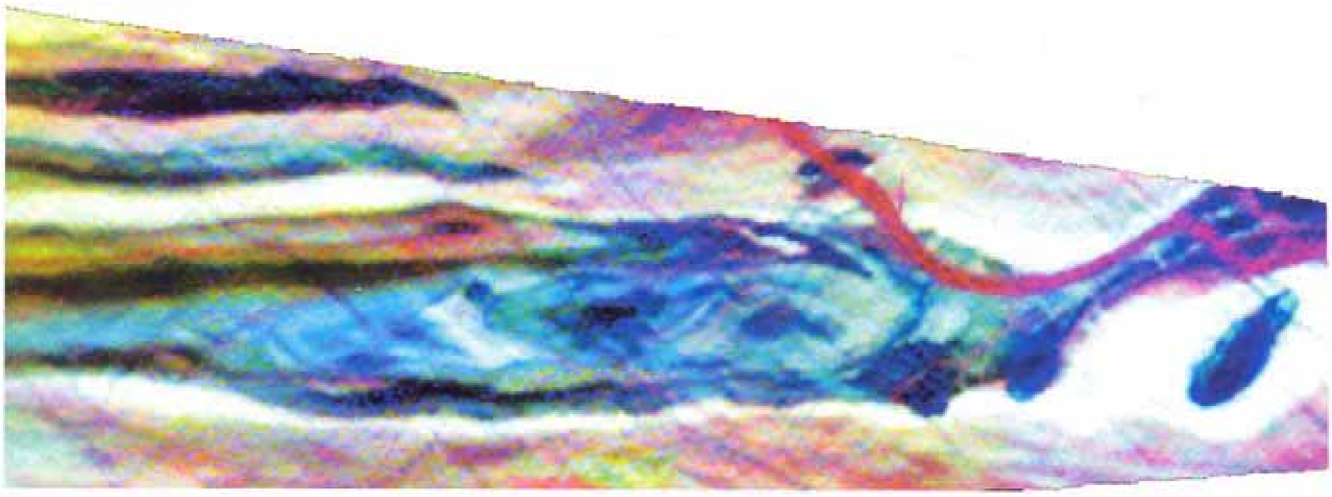
Preview

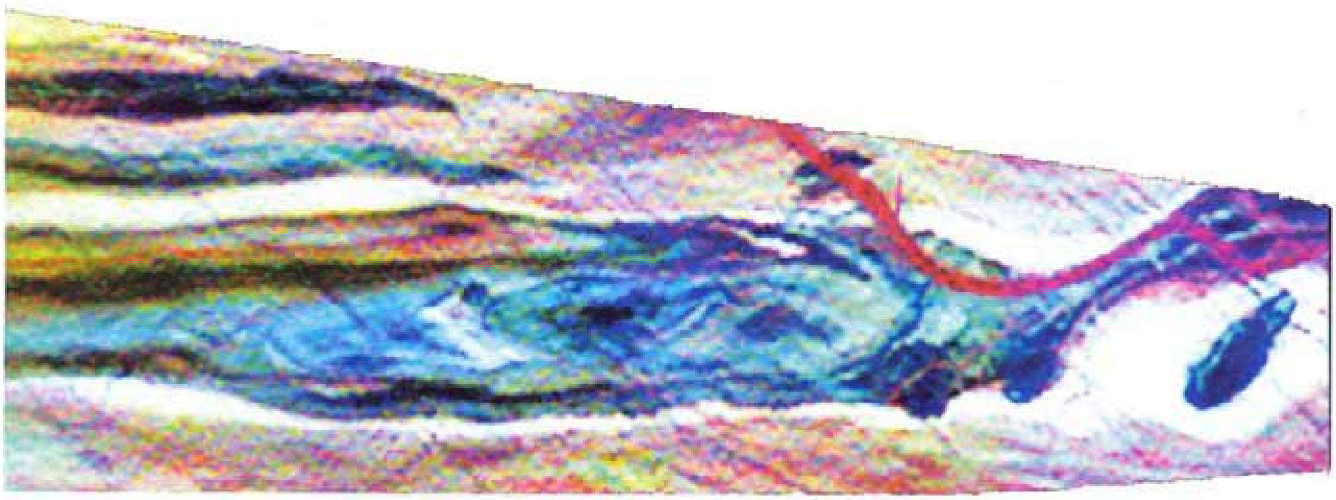
August/September 1998

Issue No. 75

SPECIAL EDITION

RADIOMETRICS WORKSHOP





In This Issue:

Contents

Feature Article

Special Features

Regular Features

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Editor's Desk

This issue is dedicated to the one day workshop titled "Recent Developments in the Processing of Airborne Gamma Ray Spectrometric Data" held in Sydney on 26 February 1998. The workshop was convened by Peter Gunn and Brian Minty and special thanks go to Brian for his contribution to this issue. The workshop was a huge success and was oversubscribed to the extent that the overflow was managed by use of live video conferencing and the use of a second room!

The three main themes were:

1. Statistical methods for noise reduction.
2. Spectral filtering.
3. Downward Continuation.

I hope that this issue provides a useful permanent record of the workshop and a milestone in the development of the science.

I recently attended the SEG DISC given by Ian Jack in Brisbane and would like to commend the SEG on this initiative. Nearly 200 people attended throughout Australia with a boost to the membership of both societies. I promised Ian that I would vote for him as President-Elect of the SEG if he promised to continue the programme. Since the SEG has already planned this it was an easy pledge to make.

The relative number of attendees in Perth, Melbourne and Brisbane served to remind me just how strong our WA branch is. A *Preview* associate editor based in Perth and preferably on the Petroleum side is keenly sought. Please contact me if you can help.

Lastly, sincere apologies to Velseis for the typo in the Corporate Members list.

Regards
Henk van Paridon, Editor

Corporate Members

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Mincom Pty Ltd
M.I.M. Exploration Pty Ltd
Oil Company of Australia
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Zonge Engineering & Research Organisation

President's Piece

Hello again, all good members! May I indulge you by continuing my musings of the previous Preview issue. In essence, how do we increase members' participation in the Society?

I wonder how many members know the ASEG has a Memorandum of Association detailing its aims, including:

- to promote the science of geophysics, and specifically exploration geophysics, throughout Australia;
- to foster fellowship and co-operation among geophysicists
- to encourage closer understanding and co-operation with other earth scientists
- to assist in the design and teaching of courses in geophysics and to sponsor student sections where appropriate.

Dare I pose some questions of these aims:

What proportion of the Society members would be aware of them? How well does the Society meet them? How many members of the Society are actively implementing them? What impetus, indeed a plan, does the Society have to monitor its performance and provide constructive feedback?

Feel mildly confronted by these questions? If not, please re-read the questions above substituting you for the Society. Are you now ready to (re)act?

We seem to live in a world that is very highly focused on the short term – what is happening tomorrow – while too readily accepting next week/year will have to look after themselves. I suggest the danger of this short-term view of life is that today's mistakes are prone to be repeated tomorrow. We seem to be too busy getting on and "doing it" to stop and learn from experiences, good and bad, ours or others. If there is a better way to do things, do we make sufficient time to recognise and implement it? To share our experiences?

A distillation of the aims of the Society suggests communication is paramount, fostered by members who initiate the process for mutual benefits. A consequence of an active Society is membership will continue to increase, providing additional funds for the Society to invest in good causes. This is the ideal Society – it has a positive feedback loop.

So why my musings? I feel we are missing out in a number of areas. Firstly, let's engender an atmosphere in which all members, in a structured way, are included. Secondly, facilitate mechanisms that allow easy implementation of communication.

This communication should not be seen as an onerous duty or an unnecessary drain on people's time. Can I suggest it at first should be within our companies, followed by inter-company and/or at State branch meetings. I'm not suggesting we sharpen the pen for a full-blown technical paper – it doesn't take much to pen a quick letter/article to *Preview*.

Most of us have experiences - tribal knowledge - that if shared actually end up strengthening the author's understanding of geophysical methods. The spirited communication that can follow will enrich all those that take part. In addition, interaction at ASEG Conferences, functions such as the recent SEG/EAGE Distinguished Instructor Short Course, are invaluable.

Why sit back and wait until others open themselves, questioning the status quo? If we insist we don't have anything worth telling, is it because we have stopped learning? To those who say your experiences are too embarrassing to admit – maybe we don't realise we are in very good company and sharing will save re-inventing the wheel. To those who say the matter is confidential – what about looking at it as one piece in a jigsaw? What is the value to an author in keeping one piece hidden when most of the rest of the puzzle is not seen?

What percentage of the Society do you think is actively involved in communication? Is it anywhere near critical mass? I suggest not.

The Society will benefit from structured, inclusive and non-unilateral direction, based on an agreed plan for active growth. Over the years, I have observed a number of well meaning, but largely actions-in-isolation, from Federal Executives' and States' branches. We seem to accept the minimal interaction too readily. It is time to agree on and implement a plan for the future of the Society.

Please seize this opportunity to make the Society stronger. State branches have been asked to search out those people with an interest to contribute – whether as someone to consult on a particular matter such as developing a plan for the Society or increasing membership, improving publications, Internet, etc or as an occasional correspondent. Contact your branch today!

PS *The Society's Memorandum of Association will be posted on the website shortly – look out for it!*

Noll Moriarty, President

ERRATA

Apologies to Don Emerson for gremlins in Rock Doctor, *Preview* 74 June 98; 'P Wave Velocities of Ores in Komatiitic Nickel Sulphide Deposits'

The x-axis titles for the graphs were unfortunately omitted. They should have been

Figure 1 Dry Bulk Density, g/cm^3, t/m3
Figure 2 Magnetic Susceptibility, SIx10-5
Figure 3 Dry Bulk Density, t/m3

In the *Preview* 73, April 98 the article by Jim Mulholland, 'Sequence Stratigraphy: Basic Elements, Concepts and Terminology' keen readers will have noticed that that third and fourth order sequences were described as being of 105 years duration. It should have read 10 to the 5 (10 superscript 5).

Executive Brief

Noll Moriaty's President's Piece last *Preview* described some of the initiatives we are considering to ensure relevance of the Society to current members and to further the Society's objectives. I was looking through the Memorandum and Articles of Association for the ASEG to clarify the Society's objectives and the document begins as follows:

The objects for which the Society is established are:

(a) To promote throughout Australia the science of geophysics especially as it applies to exploration.

(b) To promote fellowship and co-operation among those persons, firms or companies interested in the geophysical industry.

(c) To promote the good standing of the geophysical profession. We currently address these objectives through our internationally respected publications, conferences and research foundation. Two of the topic areas Noll mentioned last issue, were publicity and membership and the current Executive has some ideas in these areas.

On the publicity front, Nick and Margot are putting together a mobile ASEG booth which can be packed into crates and transported to various earth science conventions and conferences. At last year's SEG conference, Nick was impressed by the very professional, mobile, Canadian SEG booth and recommended we look at assembling a similar booth for the ASEG. The booth will be ready for the SEG conference in New Orleans in September and the ASEG conference in Hobart in November. The intention is that the booth will display information on the activities of the society such as publications, research projects and conferences and generally promote Australian geophysics. Also on publicity, Voya Kissich has accepted a position on the Federal Executive and is keen to upgrade and maintain the ASEG Web site with a National Web Site subcommittee.

A new Membership subcommittee is looking at ways to promote the science of geophysics, through increased membership. Delegates at the upcoming Hobart conference will be encouraged to fill out membership forms upon registration. Other potential target areas are universities, earth science conferences and non-member delegates from the past ASEG and AEM conferences.

The Hobart conference planning is well on track. Despite the current climate, particularly in the minerals industry, all booths have been sold, most of the sponsorship packages are taken and as at July 8th, there were 75 early registrants.

Regretfully Henk van Paridon has resigned from the Federal Executive due to other commitments. On behalf on the Executive I'd like to thank Henk for his tireless work for the Society, particularly during his time as President in 1995-96. Henk will continue his excellent work as Editor of *Preview*.

Financial Status of the Society at 19th June 1998:

Cheque Account (0800 0044)
Balance = $40,280.84
Cash Management Account (0079 1483)
Balance = $0 (acct closed)

Premium business account =	~$83,000
Term Deposit CBA (Commercial Bill) =	$158,000
Cash Management (Sands 0079 1475) =	$12,481.45
Term Deposit (Sands 5008 4219) =	$40,000
Net Cash:	**~$334,287**

Robyn Scott
Hon. Secretary

Personality Profiles

BRIAN MINTY

Brian Minty was born in Rhodesia and grew up in South Africa. He studied at Rhodes University (BSc), University of the Witwatersrand (BSc hons) and the University of Pretoria (MSc). In 1977 he started work with the South African Geological Survey on the "Karoo Airborne Geophysical Survey" - a large survey in South Africa covering almost half the country. Well airborne geophysics must have got into his blood, because he has been involved in potential fields and airborne geophysics ever since.

In 1982 he emigrated to Australia to work for Hunting Geology and Geophysics Ltd. where he was mainly concerned with the integrated interpretation of magnetic, gamma-ray spectrometric and gravity data with other remotely sensed data. In 1986 he joined the Australian Geological Survey Organisation where he currently works as a Senior Research Scientist. His research interests relate mainly to the acquisition, processing and interpretation of airborne magnetic and gamma-ray spectrometric data. In 1996 Brian completed a PhD thesis at the Australian National University on the analysis of multichannel airborne gamma-ray spectra. He has given several workshops on airborne gamma-ray spectrometry both in Australia and overseas, and is widely regarded as an expert in this field.

When he is not working, Brian really enjoys the outdoors. He used to be a keen cricketer, but now concentrates on bushwalking, mountain bike riding and trout fishing. Canberra's close proximity to Namadgi and Kosciusko National Parks make it an ideal base for these pursuits. Otherwise his favourite form of relaxation is to share a few beers with friends.

Front Cover:

MNF Noise cleaned gamma-ray survey at 80m (top) and downward continued to 10m (Red - K, Blue - U, Green - Th).

Courtesy Geof Taylor, Pitt Research

Personality Profiles

DIEDRE MARCZYNSKI
ASEG SECRETARIAT

Diedre recently joined Enterprising Events as the Secretariat Manager including responsibility for the ASEG. She has over 15 years experience in various secretary/PA and administrative roles in the corporate sector in Sydney, Melbourne and Brisbane. Most recently her roles have included Marketing Manager for a Melbourne shopping centre and General Manager for a serviced office company.

Diedre graduated from the Swinburne University of Technology with an Associate Diploma in Business – Marketing. She moved to Brisbane to be closer to family and sunshine. She will provide professional secretarial support to ASEG members, the FE and the various sub-committees.

In her spare time she is into Latin American dancing, tennis and is learning to play polo (on horseback). Learning to sail will be next. A connoisseur of fine food, wine, theatre and movies, she also enjoys spending time in the bush. From that point of view she should be very compatible with the geophysicists she will support.

Calendar Clips

1998

September 13-18
SEG Conference, New Orleans.

October 15-16
Cooper Basin Symposium, Adelaide.

October 28-30
Gas Habitats of SE Asia &Australalasia, Jakarta.

November 8-12
Australian Society of Exploration Geophysicists 13th International Conference and Exhibition. Hobart, Tasmania, Australia.

December 10-12
SEGJ/SEG/ASEG 4th Int Symposium Fracture Imaging, Tokyo.

1999

April 21-23
Murray Basin Conference, Mildura, Victoria.

Details and more events on Page 34-35

Society Briefs

New ASEG Awards

The Federal Executive of the ASEG have approved the creation of two new awards that will be available to ASEG members commencing from the forthcoming Conference in Hobart. Details of the proposed awards are set out below.

ASEG Service Certificate

In recognition of outstanding service to the ASEG , through involvement in and contribution to State Branch or Federal Committees, ASEG Publications or Conferences.

Up to two ASEG Service Certificates will be awarded every ASEG Conference. Each State Branch Committee can recommend up to two nominees by the designated deadline (in general 3 months prior to each Conference). The Federal Executive may also make recommendations (eg a member involved in Society activities such as Publications, which is normally be part of state branch activities). Nominations will be reviewed by the Honours & Awards Committee, who select and recommend potential recipients to the Federal Executive.

The award will be a framed certificate. The award does not convey special rights as for Honorary Membership.

ASEG Service Medal

In recognition of extraordinary and outstanding service to the ASEG over many years, through involvement in and contribution to State Branch or Federal Committees, ASEG Publications or Conferences.

A maximum one ASEG Service Medal will be awarded every ASEG Conference if suitable nominations are received. The Federal Executive will make the selection based on nominees for ASEG Service Certificate, or their own nominations.

The award will be a Silver Medal similar to the ASEG Gold Medal, and should have similar recognition and status as the ASEG Gold Medal. It is likely to be awarded more frequently than the Gold medal, and is quite distinct from the Gold Medal award as this is specifically designed for service to ASEG. Rights of Honorary Membership may be conveyed.

Andrew Mutton
First Vice-President

Preview Deadlines – 1998/9

October	**September 15**
December	**November 15**
February	**January 15**

ASEG Branch News

Queensland

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The Queensland Branch has been busy over recent months with the successful hosting of the SEG/EAGE Distinguished Instructor Short Course, the Annual Golf Classic, and one technical meeting.

The SEG/EAGE Distinguished Instructor Short Course - "Time Lapse Seismic in Reservoir Management" was given by Ian Jack of BP Exploration on July 10th, at Lennons Hotel Brisbane. There were 40 attendees. The DISC programme is a joint initiative of the SEG and EAGE to promote these societies around the world. The course is provided free on the condition that the attendees join the SEG/EAGE and the ASEG. As a result, 16 new ASEG members, and 25 new SEG/EAGE members were recruited. The course was sponsored by Santos, Oil Company of Australia, Schlumberger Geco-Prakla, Veritas DGC, and the Velseis Group.

The Annual ASEG Golf Classic was held at Nudgee Golf Club on Wednesday, 15th July. Congratulations to this years winners, Rio Tinto. Sponsors for the day were Schlumberger Geco-Prakla, Santos, Oil Company of Australia, Velseis, Velseis Processing, Silicon Graphics, Veritas DGC, Velocity Data, Seismic Supply International, Landmark Graphics International, & Geosoft. Grant Asser will provide a more comprehensive report in a future issue of *Preview*.

One technical meeting was held on the 3rd of June at the Spring Hill Hotel. There were two speakers. Nick Sheard of MIM presented "The effectiveness of Technology in Exploration - a Base Metal Perspective". This is a modified version of a presentation Nick made last year. The second speaker, Grant Roberts, Groundsearch, presented "Applications of Radio Imaging and Ground Radar to Mine Development". Regards, Andrew Davids Branch President

New South Wales

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The third Wednesday of each month continues to be the time for the NSW Branch regular meetings at the Rugby Club (near Circular Quay). An assortment of topics has been presented from geotechnical applications of geophysics to petroleum structural interpretation.

The presenter at the July meeting (15 July) was Ray Shaw on the "Offshore Sydney Basin - A New Structural Interpretation".

Timothy Pippett
NSW Branch President

ACT

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ASEG Prize Winners

The Australian Society of Exploration Geophysicists (ACT Branch) Prize for Geophysics has now been awarded twice. The prize is awarded to the top student in the geophysics course which is given to third-year students at the Australian National University. Prize winners so far are:
1996: Ms Gem Erica Manning
1997: Mr Denis William Hackney

WACA, on July 06, to hear Ian Jack give his one-day Short Course on Time-Lapse Seismic (4D) in Reservoir Management. As a consequence a number of attendees became new members of the ASEG.

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Monthly meetings held in the Celtic Club, West Perth on the third Wednesday of the month have included the following:

- **May 20 – Paul Wilkes**, Senior Lecturer in Exploration Geophysics at Curtin University: "CRC AMET and its role in Geophysical Education". **Tony Bint**, Nthn Australia Expln Mger, Woodside Offshore Petroleum Pty Ltd "1997 Exploration Review the momentum builds".
- **June 17 – Nick Valleau**, Managing Director of Geosoft Australia "Overview of HEM Data Processing". **Donald H. Sherlock**, Curtin University of Technology "Seismic reflections from changes in grain packing". **Dr Abdullah Mah**, Training Services Manager, ER mapper "Accurate classification using bivariates".
- **July 15 – Ian Ferguson**, University of Manitoba "Geotechnical EM projects at the University of Manitoba, Canada" Keith Woollard, GeoCom Services Australia Pty Ltd "Statistical Seismic Balancing".
- **July 06** – Distinguished Instructor Short Course DISC, sponsored by SEG, EAEG & ASEG.

One hundred attendees were at the Boundary Room, Lillee Marsh Stand, the WACA, on July 06, to hear Ian Jack give his one-day Short Course on Time-Lapse Seismic (4D) in Reservoir Management. As a consequence a number of attendees became new members of the ASEG.

New ASEG-WA website:
http://cygnus.uwa.edu.au/~raptor/asegwa/

South Australia

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Things have been fairly busy for the SA branch for the last few months with two interesting technical meetings and plans to keep things as active for the rest of the year. The May meeting was presented jointly by Robert Ryan of the Royal Flying Doctor Service and Geoff Chiggwidden of Codan Pty Ltd. Their talk was titled "Bush Telegraph: An Overview from the RFDS and Codan". While not a specifically 'geophysical' talk, it was pertinent to many of us who travel the countryside in the quest for geophysical (and other) data. The June meeting was presented by George Bertram, the director of Stratigraphic Research International. His talk was titled "Tectonic Signatures and the Use and Abuse of Isopachs". His presentation appealed as much to the structural geologist in all of us, as to the geophysicist, as it put geological reality to our ability to identify faults and other contacts. Upcoming events include the July talk, which will be presented by Rolf Klotz, the R&D manager for Western Geophysical in Australia and the Far East. His talk will be titled "Wave Equation Layer Replacement". More on that in the October *Preview*. We are also looking forward to our August meeting, which is presently planned to be our annual Industry Night. And, yes we are gearing up for the annual ASEG wine offering. Order forms should be out in the next issue of *Preview*.

Victoria

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The Victorian Branch is running an exciting program of talks and activities. On the 19th of May, Dr Andrew Long, a senior geophysicist with PGS Seres, gave a very well attended talk on 3-D seismic imaging using vertical cable technology. He demonstrated the improved illumination and imaging using vertical cable with some case study examples from the North Sea and the Gulf of Mexico. Andrew is an excellent speaker and explained the more technical aspects of the method with ease.

On the 4th of June Sven Treitel discussed Some interesting current problems in exploration geophysics. He focussed on inversion of geophysical data for subsurface properties, the uses and abuses of anisotropy, the future of reservoir imaging, and estimating reservoir permeability using 4D seismic.

The Industry Night on the June 16 was well attended, and it was interesting to see what geophysicists in Melbourne are doing at the moment. The five minutes allowed for each speaker challenged them to be informative but concise.

Ian Jack's (SEG distinguished lecturer) one day seminar on Time-lapse Seismic in Reservoir Management was held on the July 8 in Melbourne as part of his Australian lecture tour.

The August meeting will combine a wine tasting night and poster presentation by Suzanne Haydon.

Industry Briefs

GEO INSTRUMENTS SELL 500th SUSMETER

Geo Instruments of Sydney have now sold 500 Magnetic Susceptibility Meters of their Model GMS-2. The 500th Unit has been provided to Shanti Rajagopalan of Flagstaff Consultants on permanent loan. Shanti's very useful feedback earlier resulted in the only substantial change we made to the unit since its inception.

The GMS-2, Australia's own magnetic susceptibility meter, has been on the market now for almost 5 years, representing an average sale of about 8 units sold per month. It was designed to be compact and easy to use so that it could be claimed: "every geologist should have one", and it seems very many do. Its predecessor the GMS-1 evolved from a period when the popular JH8 analogue meter went off the market for a while. Geo Instruments was also at that time selling a digital unit from Canada and whilst some customers favoured a digital display, just as many others preferred the analogue display. Geo Instruments then decided to develop their own unit which combined both digital and analogue outputs to satisfy both camps. Because of a difficulty of obtaining the digital display itself, the GMS-1 made use of an off-the-shelf Fluke volt meter attached to the sensor by cable. Twenty units were sold before customer dissatisfaction with this two-hands unit forced Geo Instruments to find a source of digital displays to make a single unit, which resulted in the GMS-2. The design has not changed since that time apart from a recent response to customer feedback that the sensor be moved so that the display can be more easily read.

The number of sales must be a record for any Australian made geophysical instrument. Overseas sales have continued to grow but are largely dependent on the ability to market the unit by personal visits or through agents. Currently over 120 units are now in use in 20 different countries. The USA has the most units of any other country, followed by Indonesia, Chile and then South Africa.

Sneak Preview

- *Conference Edition*
- *Fiji Gold and how to find it*
- *More Radiometrics*
- *More Seismic Windows*

Letter to the Editor

The Editor,

Re: President's Piece – Preview Issue No. 73

Whilst being the last member to cast aspersions on the contributions made to our Society by the out-going illustrious leader S.N. (Nick/Boyo) Sheard, I feel compelled to comment on his in-sight that "companies will generally use more of a contracting style workforce and thus reduce the career geophysicist's future". Surely the "scum-bag contractor" attitude from ages past has not re-emerged in this unlikely form? Perhaps industry leaders, and educators in particular, should come to grips with the fact that the nature of employment in our profession has changed and there are no "company careers" for life. Contracting is a career option and fortunately one chosen by many outstanding geophysicists, in the past and present, as evidenced by the technical advances and quality interpretations developed by their respective contracting firms.

Respectfully submitted for comment,
Chris Anderson (Contractor)

Reply by the author

Chris certainly (and embarrassingly) had a very good point. In my "President's Piece" I did not intend to imply that a "contractor" or "consulting" career is not worthwhile or constructive. The main thrust was to highlight that a long-term career as a "Company" geophysicist is getting more and more remote. To dwell on the point somewhat, one of the values of large company "career Geophysicist" mentality was the educational or mentoring role played by such institutions. With a demise this role will have to be undertaken by contracting groups or consultants if the profession is to continue. I would like to know how many of our career contractors who have developed "technical advances and quality interpretations" were trained as Company Geophysicists.

The Contractor/Consultants are a valuable part of the Geophysical community and certainly a worthwhile profession. I would like to thank Chris for pointing this out and also accept his nomination for Publicity Sub-Committee who have to prepare a career booklet and display.

S.N. Sheard

Recent Developments in the Processing of Airborne Gamma-ray Spectrometric Data

Brian Minty
Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601

A one-day workshop titled "Recent Developments in the Processing of Airborne Gamma-ray Spectrometric Data" was held in Sydney on 26 February 1998. The workshop was convened by Peter Gunn and me, and was jointly sponsored by AGSO and the ASEG. The workshop was convened in response to a perceived interest in several new methodologies that have been developed over the past few years for the processing of airborne gamma-ray spectrometric data. Well, I must admit that we totally underestimated the response! We booked a room at the Manly Pacific Parkroyal to accommodate 100 on the assumption that about 30 would register for the somewhat esoteric program. However a flood of last minute registrations pushed the total registrations to 130 – including 30 international delegates. In a frantic bid to accommodate all the interested participants, we settled on live video conferencing of the proceedings into a second room at the hotel where the overflow was accommodated.

The workshop papers and subsequent discussions centred on three main themes.

(a) *Statistical methods* for reducing noise in multichannel gamma-ray spectrometry. These methods are currently not well understood, and were the main theme of the workshop. The methods seek to remove noise from observed spectra which are then processed in the normal way. The methods essentially extract the dominant spectral shapes ("components") from the observed spectra. These principal components are then used to reconstruct "smooth" spectra. **Jens Hovgaard** (Exploranium) described the NASVD method (Noise Adjusted Singular Value Decomposition), and **Andy Green** (CSIRO) described the MNF method (Minimum Noise Fraction) and explained the difference between the statistical methods, such as NASVD and MNF, and the more conventional spectral fitting approach to multichannel spectral analysis. **Bruce Dickson** (CSIRO) described his experiences with the application of both the NASVD and MNF methods, and I presented the results of research I did in collaboration with **Phil McFadden** (AGSO) on a new implementation of the NASVD method. **Bob Grasty** (Exploranium) gave an overview of the development of the NASVD method, and explained why the statistical methods give superior noise reduction to the spectral fitting method.

(b) *The spectral fitting method.* This method is based on the least-squares fitting of component spectra to the observed spectra. The component spectra in this case generally associate with a source of gamma-radiation and must be previously determined in some way. **Ed Reeves** (Tesla Airborne Geoscience) showed component spectra derived directly from survey data, and **Paul Roocke** (World Geoscience Corporation) described the "Spectra Plus" method where the component spectra are estimated through Monte Carlo simulation. **Martin Schneider** (Des Fitzgerald & Associates) showed examples of multichannel processing using INTREPID software for both NASVD noise reduction and atmospheric background estimation. **Tanya Braginskaya** (VIRG-Rudgeofizika) gave an overview of the processing methodology used at VIRG, including a novel method for correcting airborne gamma-ray data for rugged topography.

(c) *Downward continuation of airborne gamma-ray data.* The theory for downward continuation has been available for some time, but it is only with the advent of multichannel processing methods that the errors in the processed data are reduced to the point where downward continuation is now feasible. **Geof Taylor** (Pitt Research) showed impressive results of the downward continuation of high-quality data from detailed gamma-ray surveys. **Steve Billings** (Sydney University) described current research into improved modelling of the response of airborne gamma-ray detectors. This will result in more accurate and stable downward continuations. **Peter Gunn** (AGSO) explained the theory for downward continuation from irregular surfaces.

The workshop was structured to enable plenty of time for discussion. This was just as well, since some participants had strong opinions on the merits or otherwise of the new methodologies. The discussions proved to be spirited, and continued into the refreshment breaks and well after the official workshop close. This is the real value of meetings such as this – the opportunity to network and share ideas and experiences. Although we did not reach a consensus on the best way to incorporate the new methods into standard processing procedures, I think everybody left the workshop with a far greater understanding of the methodologies and issues involved. The following account is based on my own understanding of the main issues discussed at the workshop. I've drawn on the material presented at the workshop, but the views I express here are not necessarily shared by the other participants. Abstracts of the workshop presentations are included in this issue of Preview. The paper by Braginskaya and Zubov is reproduced in its entirety. The paper by Schneider was published in the April edition of Preview.

Statistical Methods for Reducing Noise

Although modern spectrometers record at least 256 channels of data in the energy range 0-3 MeV, the conventional approach to the processing of these data is to sum the spectra over 3 broad energy windows for the estimation of potassium (K), uranium (U) and thorium

(Th) - the so-called "3-channel method". The aim of multichannel processing methods is to extract more of the information present in the observed spectra. The statistical methods seek to remove noise from the raw spectra. The conventional windows are then sampled in the normal way and the window data processed using the 3-channel method.

The NASVD method, which is similar to principal component (PC) analysis, was originally developed by Hovgaard (1997) for the analysis of multichannel gamma-ray data for the detection of exotic sources in nuclear emergencies. The method was subsequently adapted for natural radioelement mapping by Hovgaard and Grasty (1997). The procedure transforms the observed spectra into orthogonal spectral components that are ordered according to the degree to which each component contributes to the shape of the observed spectra. Since the signal tends to correlate between spectra, this ends up in the lower-order components. The random noise, on the other hand, does not correlate from one spectrum to the next, and tends to end up being represented in the higher-order components. The spectra are "smoothed" by reconstructing them from the lower-order components only.

Jens Hovgaard went to great lengths in his presentation to point out that the NASVD method does differ from the more familiar principal component method. The principal component method requires that the data are centred on the mean and have equal variance. This is not the case for airborne gamma-ray spectra. But airborne spectra are easily scaled to equal vàriance in each channel. Since counting errors in gamma-ray spectrometry are Poisson distributed, the variance of a particular channel count rate is the same as the mean count rate for that channel. Also, the best fit of the mean spectrum to each input spectrum usually provides a good approximation to the mean count rate (and hence variance) for each channel. Thus, by scaling each observed spectrum by the best fit of the mean spectrum to the observed spectrum, we can normalise the variance in each channel of each spectrum to unity without otherwise distorting the spectra. Of course, this means that the component spectra need to be later unscaled by the same "mean spectrum". The normalisation is thus based on the assumption that the best fit of the mean spectrum to individual spectra is a good measure of the channel variances. This may not be the case where the shape of the gamma-ray spectra vary significantly within a survey area. The centering problem is overcome by using singular value decomposition to analyse the dispersion of the data around the origin rather than around the mean.

The MNF method (Green et al., 1988) is a more general method for removing noise from multispectral data. Green et al., (1988) showed that the principal component method is not very effective at extracting the dominant spectral components in situations where the noise correlates between channels, or the noise in each channel is of unequal variance. Their solution involves two linear transformations of the data. The first transformation decorrelates and normalises the noise to equal variance in each channel. The second transformation is a standard PC transformation on the now "noise-whitened" data. Green et al. (1988) combined the two transformations into a single transformation and called it the Minimum Noise Fraction (MNF) transform. The MNF transform orders data into new components by decreasing signal/noise ratio. The noise is again removed by discarding the higher order components before doing the inverse transform.

NASVD vs MNF

The main difference between the NASVD and MNF methods is the manner in which the input data are normalised for noise. The NASVD method is tailored for gamma-ray data and uses a specific noise model based on the Poisson distribution of the noise. This model assumes that the covariance between channel count rate errors is zero. The method accommodates unequal variances between channels, as well as unequal variances in the same channel of successive spectra. The input data are thus scaled both between channels and between observations. This is important, as the variance in airborne channel count rates depends on the mean count rate at each observation point and this can vary significantly within a survey area.

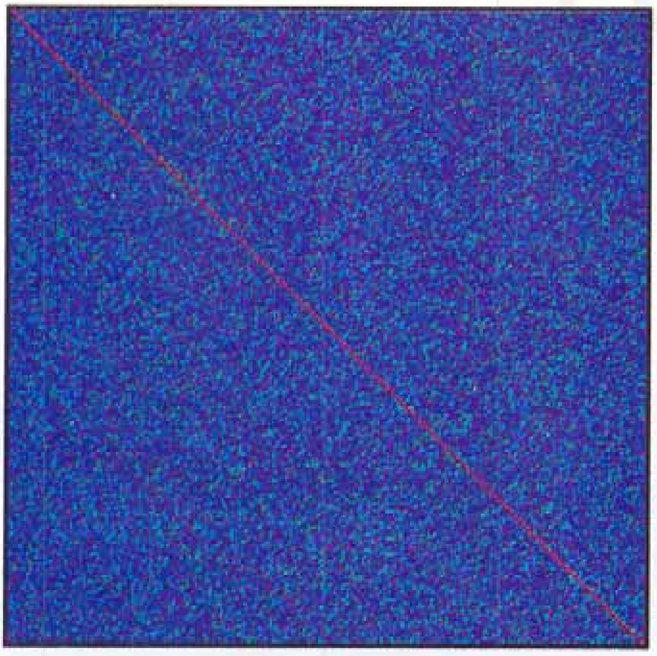
The MNF method, on the other hand, estimates the errors directly from the input data using an along-line differencing technique. This enables an average variance and covariance for each channel to be estimated, and these are assumed to be constant for all of the input data. This works well for remotely sensed data where the errors vary between bands but are constant for all data points within a band. But this method of estimating the errors does not accommodate changes in gamma-ray errors due to changes in the mean count rate within a survey area.

So, can the MNF method be tailored for use with gamma-ray data? Very easily, in fact. Andy Green pointed out in his presentation that if you do have a good model for the noise, then you should use it! The scaling procedure used in the NASVD procedure can be applied to condition the input data prior to processing using the MNF method. This effectively overcomes any objection to using the MNF procedure in areas where the mean count rate varies significantly.

This leaves the MNF procedure with the advantage of being able to accommodate a covariance between channel count rate errors. But is there such a covariance? It is generally accepted that the decay of radioactive nuclei in a medium and the scattering and/or absorption of resulting gamma rays take place independently of the decay of other nuclei in the medium and the interaction of their gamma rays with the medium. But does this translate into independent channel count rates? Not necessarily. Consider the effect of "accidental summing" on the measured channel count rates. If two gamma-ray photons (with energies *A* and *B*, say) simultaneously strike a single detector crystal (or adjacent crystals in the Exploranium GR820), they will be recorded in a single channel with energy (C, say) equal to the sum of the two photon energies. The channel with energy *C* thus has an extra count at the expense of the channels with energy *A* and *B*. This, I believe, introduces a covariance between channel count rate errors.

But is this covariance significant? Figure 1(a) shows the noise covariance matrix for a series of spectra recorded with AGSO's airborne geophysical research

(a)



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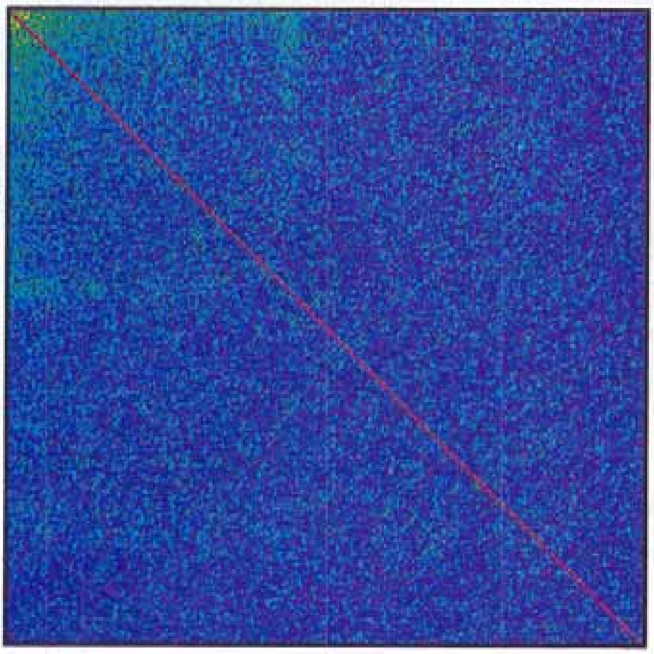
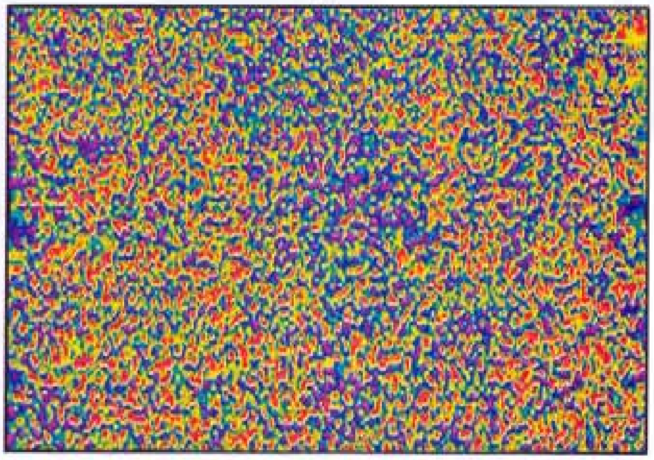


Figure 1. (a) Noise covariance matrix for a series of spectra recorded over the same point on the ground, and (b) noise covariance matrix for spectra recorded along a survey line. In both cases the noise was estimated using the MNF along-line differencing technique.

aircraft stationary on the ground. The noise was estimated using the same along-line differencing technique used in the MNF procedure. The matrix has been normalised to unit variance along the main diagonal. The off-diagonal elements are close to zero and show no evidence of structure. This suggests that the covariance between channel count rate errors is small. However, the covariance matrix calculated in the same way for a line of survey data shows evidence of structure in the off-diagonal elements at low energies [Figure 1(b)]. This suggests that the MNF differencing procedure for estimating the noise covariance matrix is interpreting geological signal as noise – i.e. geological signal that correlates between successive "difference" spectra is interpreted as a covariance between channel count rate errors. This may explain why the MNF procedure consistently smooths gamma-ray data to a greater degree than the NASVD method. The method interprets short wavelength geological signal as noise.

Note that energy drift during the course of a survey may be a further complicating factor for the estimation of channel covariance using the along-line differencing technique. The estimation of the covariance is based on the assumption that each channel count rate is drawn from a random distribution about the true mean, but that this randomness is somehow linked between channels in individual spectra. Energy drift gives a systematic correlation between channels of different spectra in a survey area. For example, if spectrum 1 has the K photopeak in channel A, and spectrum 2 has the K

(a)



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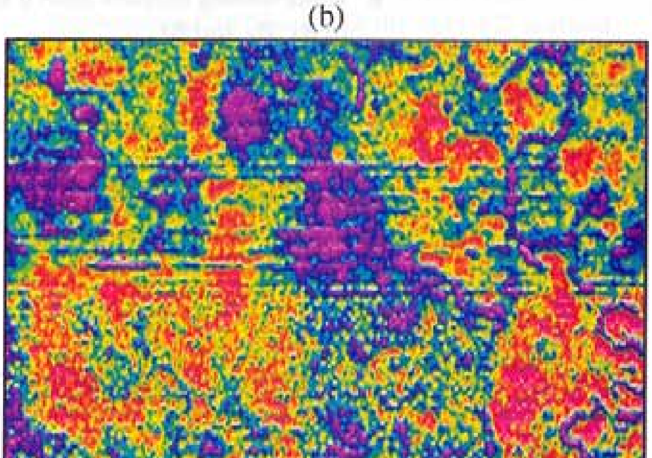

Figure 2. Estimated U concentrations for the Jemalong Plains survey processed using (a) the conventional 3-channel method, and (b) the 3-channel method after NASVD smoothing of the raw spectra.

photopeak in channel B, then this introduces a systematic correlation between channels A and B which may be falsely interpreted as a covariance.

Improved NASVD/MNF smoothing

The degree to which the NASVD or MNF methods remove the noise from raw gamma-ray spectra is highly dataset dependent, and in some cases the noise reduction can be quite dramatic. A good example is the Jemalong Plains survey flown by AGSO in 1994. The survey covers an area of approximately 16 km by 9 km, and was flown at 60 m height and 100 m line spacing using a 32 litre detector. Figure 2 shows the U window data processed using both the conventional 3-channel method, and the 3-channel method after NASVD smoothing of the raw spectra. The reduction in noise after NASVD smoothing is striking.

Phil McFadden and I presented a paper at the workshop where we speculate that the reason for this remarkable reduction in noise is because there is a high correlation between Th and U in the Jemalong Plains survey area, and the survey was flown on a day of low and near-constant atmospheric radon concentration. In general, the smaller the variation in spectral shape within the input signal, the greater the noise reduction. This was used to develop a new implementation of the NASVD method that can be applied to large survey datasets. Instead of processing the spectra by either survey or flight, the entire survey database is sorted into clusters on the basis of similarity in spectral shape. The application of the NASVD or MNF methods to these clusters typically halves the K, U and Th fractional errors that would otherwise be obtained. Figure 3 shows an example of the application of the method. A paper on the method will be presented at the ASEG Conference in Hobart in November.

Spectral Fitting Methods for Reducing Noise

Spectral fitting has been used in laboratory spectrometry for many years. Observed spectra are considered as a linear combination of several discrete components, where each of the components associates with a source of gamma-radiation. The problem is to determine the linear combination of the components that best fit the observed spectra in a least-squares sense. The method is thus a multichannel version of background removal combined with the 3-channel stripping procedure.

For airborne surveying, the spectral fitting method requires an *a priori* model of airborne spectra and their variation with survey height and source concentration. The difficulty is in adequately determining these *a priori* component spectra. Minty et al. (1998) acquired K, U and Th component spectra as functions of survey height using calibration sources on the ground and used wood to shield the detectors and thus simulate the attenuation of the gamma rays by air. A parametric model based on a principal component analysis of these spectra as functions of height is used to find the effective heights at which the components best fit the background-corrected airborne data. The component spectra for these heights are then fitted to the background-corrected observed spectra.

The determination of suitable component spectra has been a limiting factor in the widespread use of the spectral fitting method. It was thus interesting to see two new approaches to the determination of these components described at the gamma-ray workshop. Ed Reeves showed component spectra derived directly from survey data (Figure 4). These were estimated using a technique based on the correlation between processed 3-channel count rates and the observed spectra. Paul Roocke showed examples of component spectra estimated through Monte Carlo simulation of gamma-ray transport (Figure 5).

A big incentive for making the investment in acquiring good quality component spectra is their application to multichannel methods for estimating atmospheric radon background. Minty (1998) describes two multichannel approaches to the estimation of atmospheric radon background. Ed Reeves and Martin Schneider showed several good examples at the workshop of the application of similar multichannel methods to background removal.

Statistical Methods vs Spectral Fitting

The statistical methods appear to be significantly more effective at reducing noise than the spectral fitting method. As an example, the fractional errors associated with various type of processing for AGSO's Fowler's Gap survey are shown in Table 1. This gives a fair indication of the noise reduction capability of the various methods. A convenience of the statistical methods is that no calibrations other than those required for the conventional 3-channel method are required. The main disadvantage of the method is that we do not currently have an objective measure of how many components should be use to reconstruct the smooth spectra. In my opinion, it is possible to reject a component needed to model a subtle anomaly, and in this case the anomaly will be lost. All the same, for geological/regolith mapping applications, this is currently the preferred method for processing multichannel data.

Table 1. Fractional errors for the Fowler's Gap multichannel airborne gamma-ray spectrometric data processed using the 3-channel method, the spectral fitting method, the NASVD method implemented by flight, and the NASVD method implemented by cluster.

	Average deviation (%)		
Implementation	K	U	Th
3-channel method	7.1	33.3	8.4
Spectral fitting	6.5	23.5	6.2
NASVD by flight	6.1	19.2	5.4
NASVD by cluster	2.9	9.8	3.3

The spectral fitting method requires a physical model of observed airborne spectra as a sum of discrete components. This model must be able to accommodate changes in the shape of K, U and Th spectra with survey height. If the model is good, then it should be able to resolve all possible sources of anomalies. The disadvantage of the method is that good quality component spectra are essential, and the acquisition of these can be expensive. Monte Carlo simulation of the

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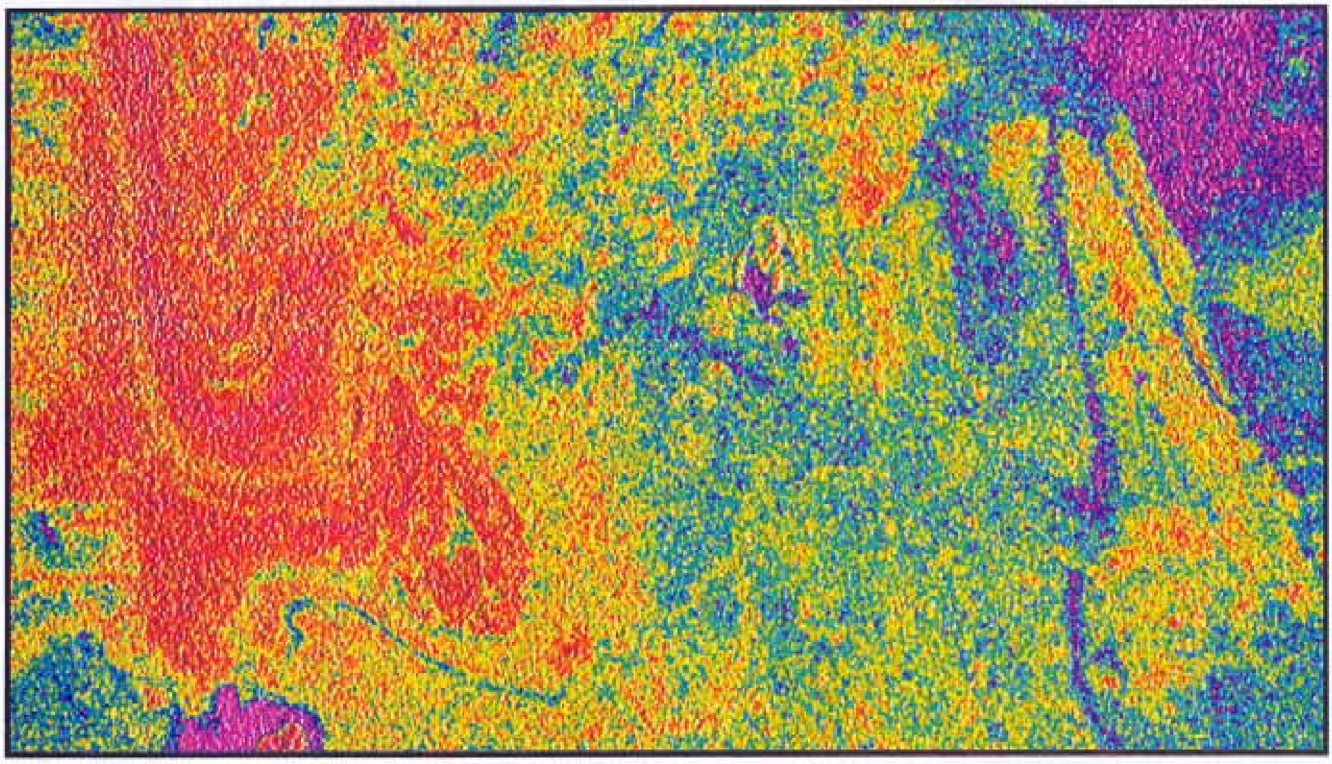

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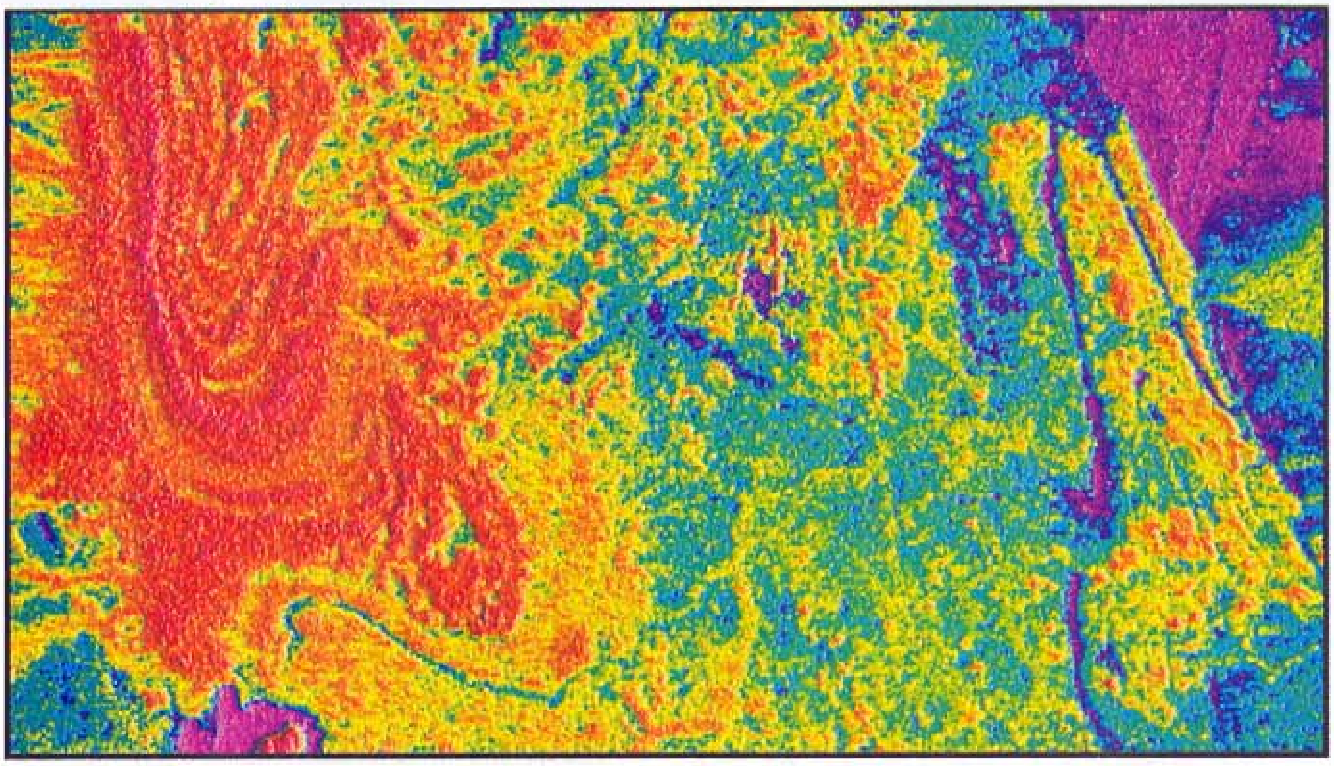


Figure 3. Estimated Th concentrations for part of the Fowler's Gap survey area. The data were processed using (a) the conventional 3-channel method, (b) the 3-channel method after NASVD smoothing by clusters.

components may provide the best solution. The advantage of the spectral fitting method is that it can be used to extract additional information (other than K, U and Th source concentrations) from the observed spectra. This additional information is the contribution of the background components to the observed spectra, and the

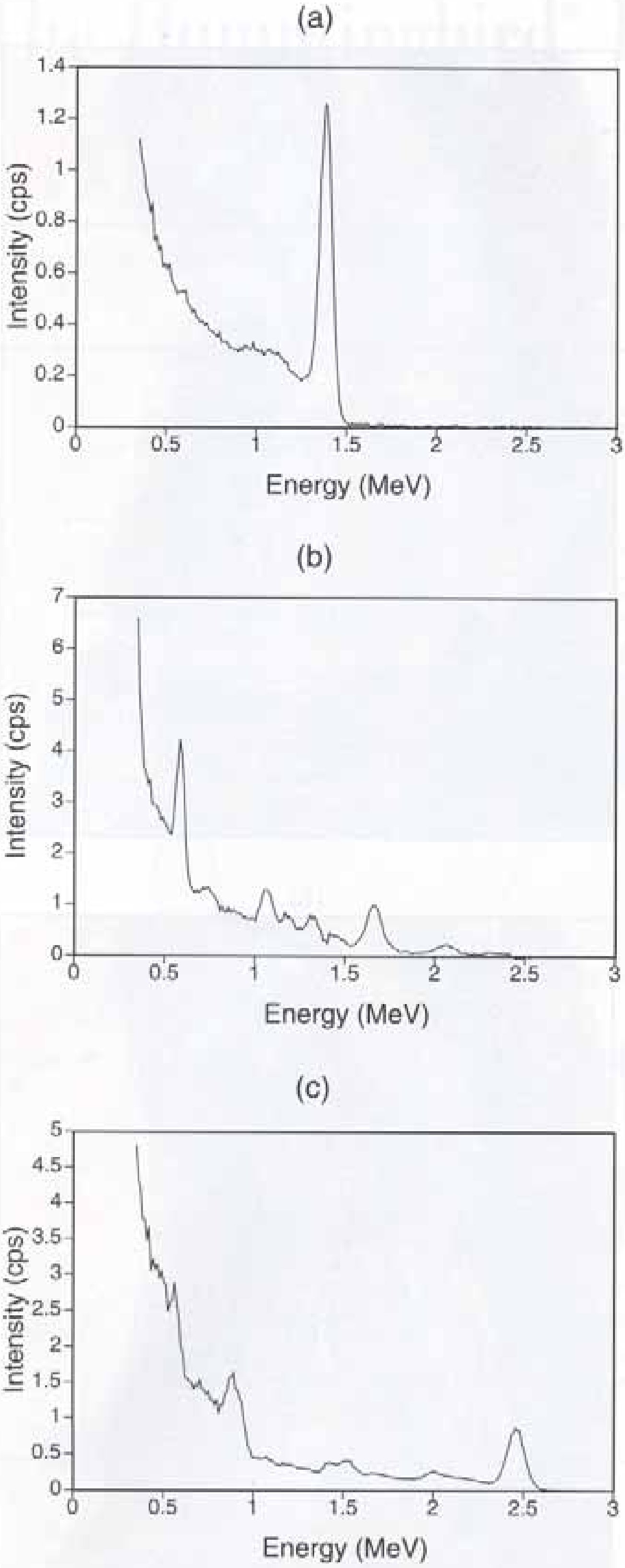


Figure 4. Examples of (a) potassium, (b) uranium, and (c) thorium component spectra derived directly from survey data (figure courtesy of Ed Reeves, Telsa Airborne Geoscience).

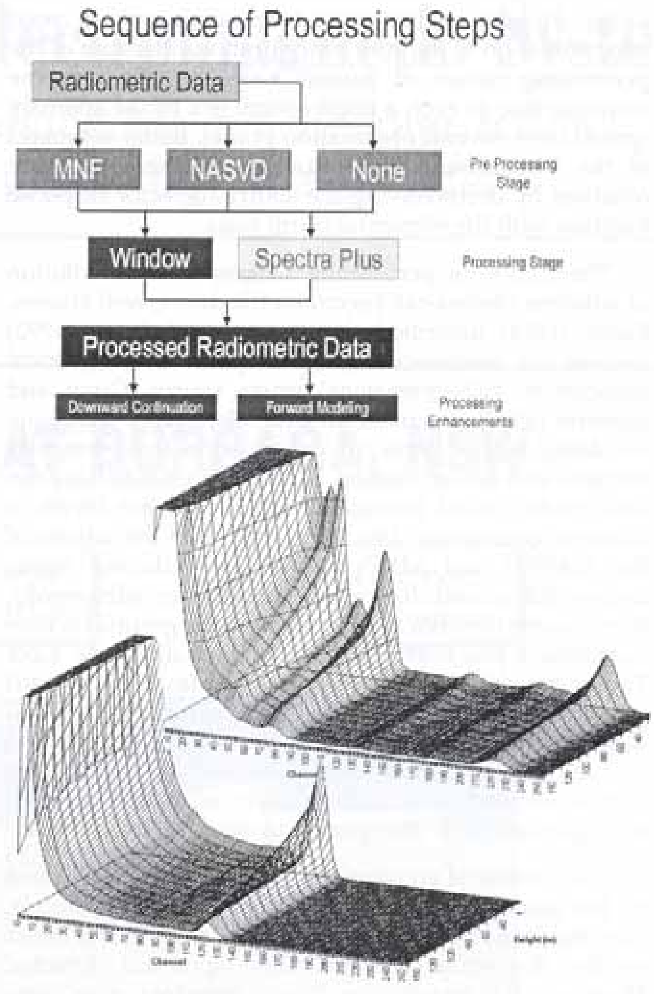


Figure 5. Schematic of "Spectra Plus" processing methodology. Component spectra derived through Monte Carlo simulation of gamma-ray transport are shown (figure courtesy of Paul Roocke, World Geoscience Corporation).

effective height of the detector above K, U and Th sources. These latter parameters (the "effective" heights) may have application to regolith mapping (Minty et al., 1998). The effective heights are also used to determine the component spectra used in the multichannel "stripping" procedure. This is an improvement over the conventional 3-channel method where the radar altimeter reading is used to determine the stripping ratios. The radar altimeter reading is not always a good measure of the effective height of the detector above the sources, and this can introduce a bias into the processed data.

Note that the statistical methods and spectral fitting may be used in a complementary manner. It is possible to apply the spectral fitting method to spectra that have been smoothed using either the NASVD or MNF methods. Although this does not appear to produce any further reduction in K, U and Th concentration errors, there may be some benefit in reducing the bias in the estimates of K, U and Th concentrations and improved estimates of atmospheric radon background.

Deconvolution / Downward Continuation

Airborne gamma-ray spectrometric data are processed to elemental count rates at the nominal survey height. These count rates are then converted to elemental concentrations by a simple scaling of the count rates at each observation point by pre-determined sensitivity coefficients. The sensitivity coefficients are empirically determined from calibration flights over a calibration range. However, this procedure offers only a poor approximation to the true concentrations. Because of the penetrating nature of gamma radiation, the airborne response due to even a point source is a broad anomaly spread over several observation points. Better estimates of the true ground concentrations of the source are obtained by deconvolving the source/detector response function with the elemental count rates.

The theory for performing a rigorous deconvolution of airborne gamma-ray spectrometric data is well known. Gunn (1978) described the theory, and Craig (1993) derived the frequency domain response of a spherical detector to a 2-dimensional prism source. Gunn and Almond (1997) described an equivalent layer technique for doing both downward continuation from irregular surfaces and deconvolution. But these methods have not been widely used because of the high noise levels in airborne gamma-ray data. However, with the advent of the NASVD and MNF methods of reducing noise, deconvolution and downward continuation (deconvolution to some theoretical surface above the ground) is now becoming a practical reality for high-quality data. Geof Taylor showed some impressive examples of downward continuation (Figures 6 and 7) using the method described by Craig et al. (1998?). The method is applied to gridded data, and the data must be of a high quality. The data shown in Figure 6, for example, was acquired at 30 m height and 50 m line spacing using a 33 litre detector.

The successful application of deconvolution is limited by the quality of the response function of the detector. The response function described by Craig (1993) is based on the theoretical response of a spherical detector. However, the rectangular "slab" detectors now commonly used have a directional sensitivity. Steve Billings has modelled the response function of the slab detectors using geometrical arguments. An example of his results is shown in Figure 8. The slab detectors present a greater surface area to sources beneath the survey aircraft than to sources displaced laterally. Their response function thus shows a faster fall-off of radiation intensity with lateral distance from the source. The use of this response function can be expected to improve deconvolution in two ways. First, the deconvolved data will be more accurate. Second, in recognition that most of the measured radiation in fact originates close to the detector, the deconvolution should be more stable.

Correcting For Rugged Topography

Height corrections in airborne gamma-ray surveying are based on a model of a flat earth. In areas of rugged topography, height correction and topographic errors can be significant. For survey lines flown parallel to a slope there is a lateral contribution of radiation to the detector from sources closer than the distance measured on the radar altimeter. Similar errors occur on draped surveys, and the size of the errors depend on the attitude of the aircraft (climbing or descending) and the directional sensitivity of the radar altimeter. These errors are exacerbated because the height of the aircraft above the ground on the "up hill" lines is generally much greater than on the lines flown in the opposite direction.

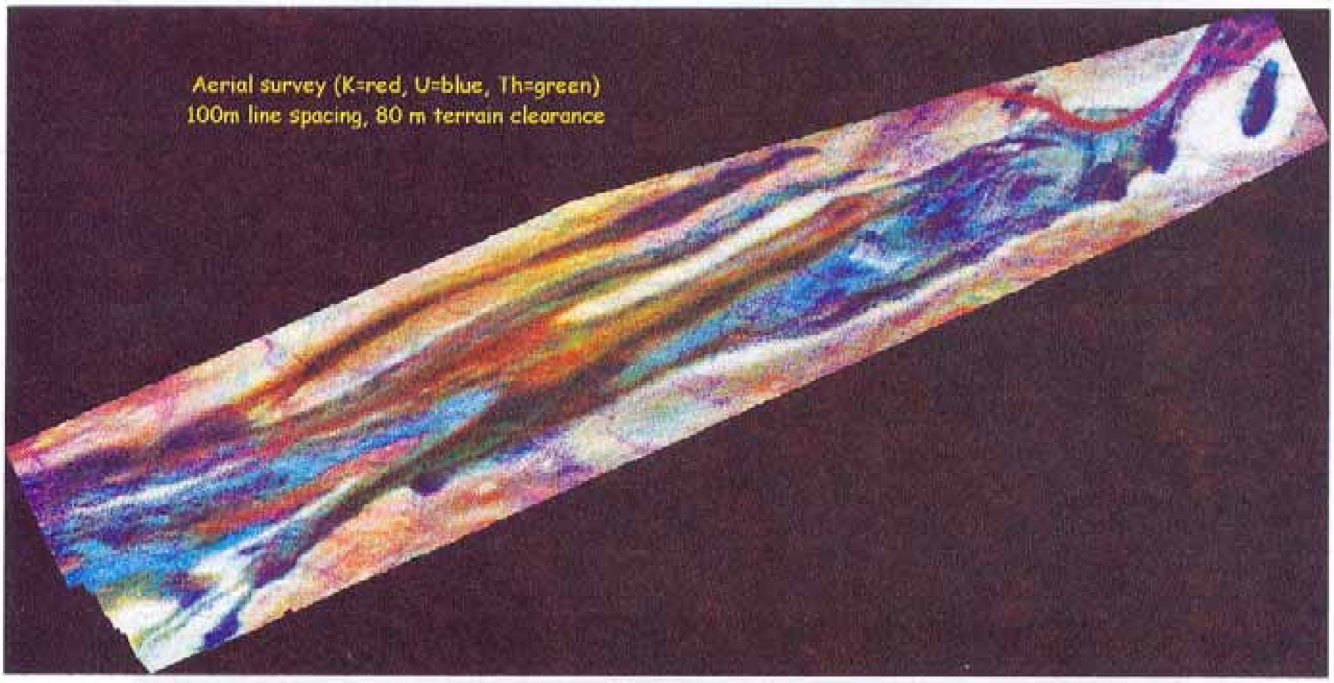
Tanya Braginskaya described an empirical approach to the correction of these topographic effects. Each affected area is analysed separately. Window count rates

(a)

(b)

Figure 6. Ternary images of the Lynas survey are, WA, (a) processed using the 3-channel method after NASVD smoothing, and (b) after downward continuation of the processed data (figure courtesy Geof Taylor, Pitt Research).

(a)



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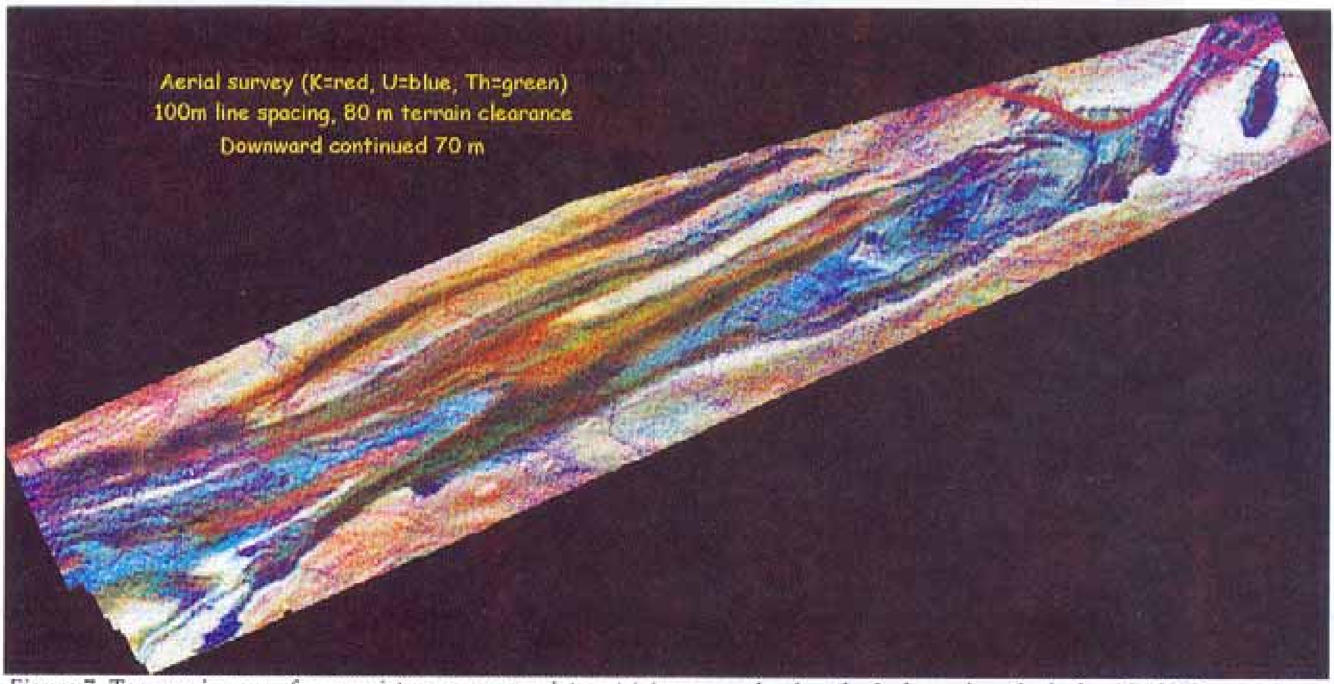

Figure 7. Ternary images of a proprietary company data set (a) processed using the 3-channel method after NASVD smoothing, and (b) after downward continuation of the processed data (figure courtesy Geof Taylor, Pitt Research).

as functions of detector height for lines flown in each direction are compared with a theoretical height dependence to estimate a correction for each height and line direction. These corrections remove any topographic dependence in the processed data. The full text of Tanya's paper is reproduced in this issue of *Preview*.

Software Solutions

Multichannel processing of airborne gamma-ray spectrometric data can be a bit intimidating for those new to the method. Attention to detail is important. For example, if spectra are not adequately energy calibrated, this can lead to large errors in the estimation of atmospheric radon background. Commercial software

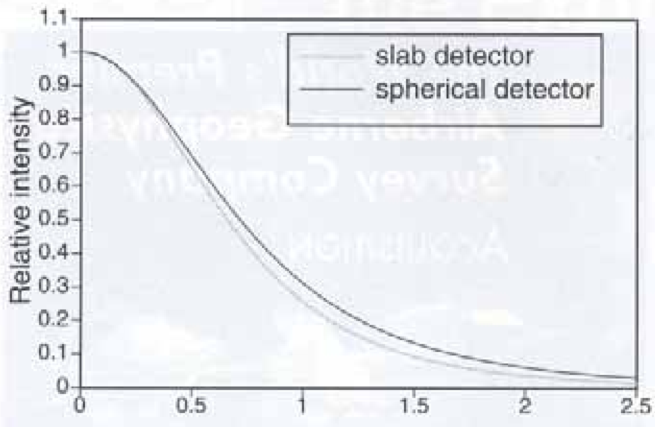

Figure 8. Theoretical detector response for both a spherical detector and a rectangular slab detector (figure courtesy Steve Billings, Sydney University).

packages for the processing of multichannel gamma-ray spectra are now available. Martin Schneider showed examples of the application of the INTREPID software package to multichannel processing. The software incorporates most of the recent developments in processing methodology including NASVD smoothing, multichannel background estimation, and downward continuation. An essential feature of such software is the capability of the system to provide feedback to the processing analyst. Figure 9 shows some of the graphical feedback windows used by the INTREPID processing system.

Conclusions

The Gamma-Ray Workshop provided a great opportunity to discuss new developments in gamma-ray spectrometry. All of the participants gained from the occasion through an improved understanding of the new methods.

These are exciting times for airborne gamma-ray spectrometry. In a science where improvements are usually only in small increments, we have seen spectacular improvements in the past couple of years. The improvements greatly increase the amount of geological information an experienced interpreter can extract from processed gamma-ray spectrometric data, and will lead to enhanced and expanded geological, environmental and land use applications of the method.

Acknowledgements

The contributions of both presenters and participants to the success of the gamma-ray workshop is gratefully acknowledged. The workshop was jointly sponsored by the Australian Geological Survey Organisation and the Australian Society of Exploration Geophysicists. My understanding of the issues discussed in this paper has benefited from many discussions with Phil McFadden. This paper is published with the permission of the Executive Director, Australian Geological Survey Organisation.

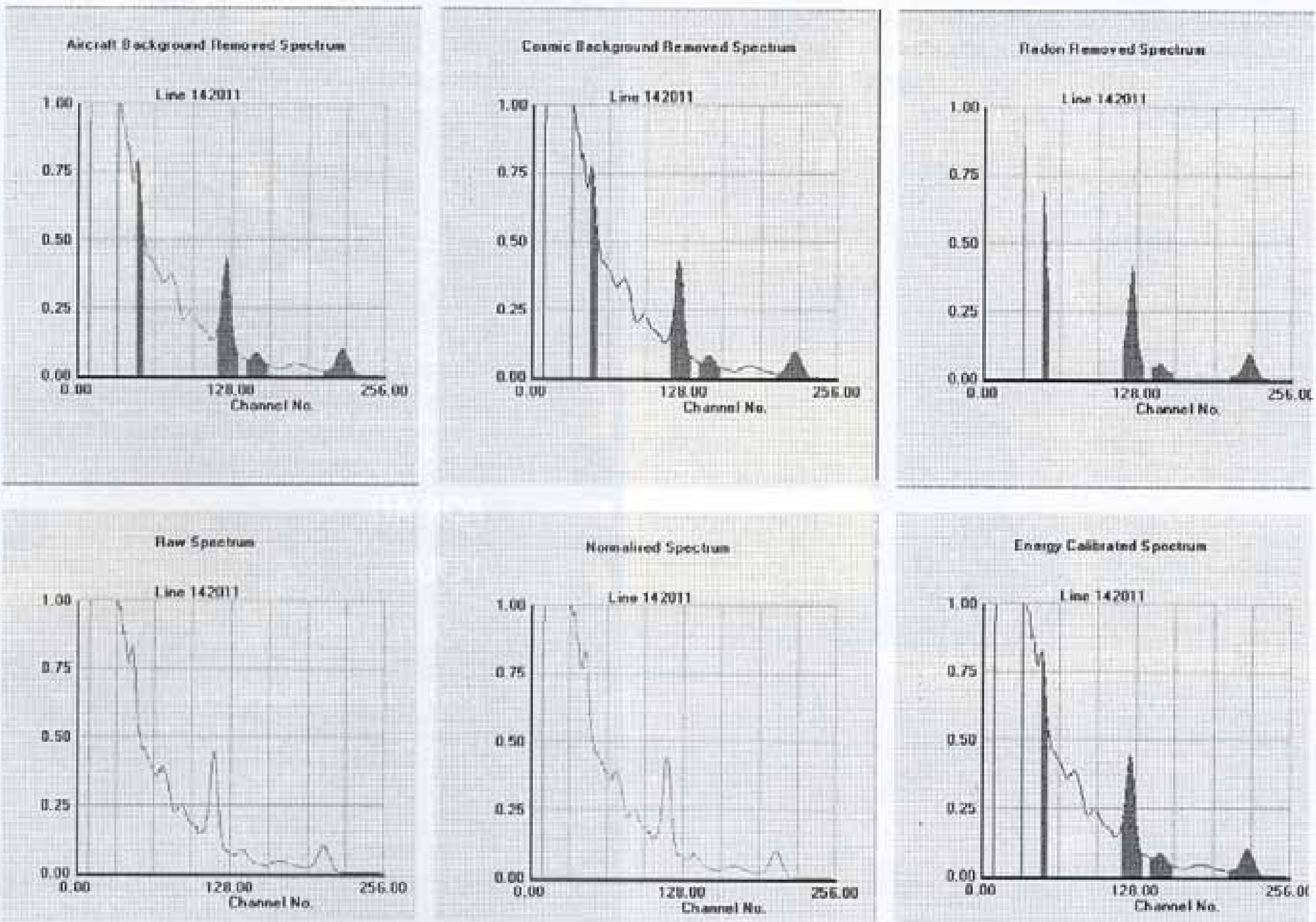

Figure 9. Examples of the graphical feedback windows used in the INTREPID processing system (figure courtesy Martin Schneider, Des Fitzgerald & Associates).

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Gamma-ray Workshop Abstracts – Index

- **Subspace projections for multivariate data – Do we use the statistics or the physics?**
  Andy Green
- **Experiences with application of noise reduction techniques to AGRS**
  B.L. Dickson and G.M. Taylor
- **Improved NASVD Smoothing of Airborne Gamma-ray Spectra**
  B.R.S. Minty and P.L. McFadden
- **Case Studies in Principal Component Analysis and Development in Calibration Techniques**
  Martin Schneider
  (Published Preview 73, April 1998)
- **Some Thoughts on Multichannel Processing of Airborne Gamma-ray Data**
  R.L. Grasty
- **Experiences with downward continuation of AGRS data**
  G.M. Taylor and B.L. Dickson
- **Modeling detector response in airborne gamma-ray spectrometry**
  Stephen Billings
- **Deconvolution of Radiometric Data Using Equivalent Layers**
  P.J. Gunn
- **Some features of airborne radiometric data processing**
  T.G. Braginskaya and E.I. Zubov
  (To be published in full, Preview 77, December 1998)
- **'Compton Counting' and Noise Reduction**
  Ed Reeves

Gamma-ray Workshop Abstracts

Subspace projections for multivariate data - Do we use the statistics or the physics?

Andy Green
CRCAMET

This talk will explain the relationships between filtering with the Principal Components (PC) Transform, the MNF transform, the Fourier Transform and inversion techniques based on our knowledge of known gamma ray spectra.

Because airborne radiometric spectra are basically derived from the mixing of three fundamental spectra the true dimensionality of the data is low and almost all spectra can be represented as linear combinations of a restricted set of eigenspectra. This is the same as saying that the data occupies a distinct sub-space of low dimensionality buried in the very high dimensional (often 256) space in which the data is initially acquired.

The statistically-based noise cleaning procedures described here and the normal inversion to radio-element concentrations involve a projection of the 256-D data onto this low dimensional (often ~6-D) subspace. Such projections can provide strong noise suppression because, while there is no suppression of signal strength (because all the signal data lies in the subspace), the noise is attenuated to the extent that it projects out of the signal sub-space.

The difference between the statistical methods and the inversion method is that, in the latter, we assume we know the position and orientation of the signal subspace within the original data space. In contrast the statistical methods attempt to locate it based on the variability of the data. The differences between the various statistical procedures arise from the different assumptions they make about the covariance structure of the noise. PC methods assume the noise is uncorrelated and of equal variance in all channels. Noise Adjusted PC's assume that the noise is uncorrelated but with different variance in each channel. The MNF procedure allows correlated noise and unequal variance.

Experiences with application of noise reduction techniques to AGRS

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Hovgaard and Grasty (1997) recently showed that by processing large blocks of data (104 spectra), using noise-adjusted singular value decomposition (NASVD) they could reduce the noise in individual spectra before the processing by conventional methods to yield images of the K, U & Th ground distributions. We have implemented a similar procedure which is very effective on many data sets. However, we have found some data sets show little or no improvement in noise quality as a result of what appears to be fluctuating gain in the spectrometers used to collect the data.

We have investigated the use of the Maximum Noise Fraction (MNF) method proposed by Green et al. (1988) for ordering multispectral data in terms of image quality for reducing the noise. The MNF method is essentially two sequential Principal Component transformations; the first decorrelates and normalises the noise in the data, using differences between adjacent points as an estimate of the noise covariance, and the second, is a standard PC transformation of the noise-whitened data. As with the NASVD method, MNF is applied to the raw spectra prior to conventional processing of the spectra to give ground concentrations.

To illustrate the effectiveness of the MNF method, the following table contains coefficients of variation (mean/standard deviation) for a featureless area of a recent low-level, high-resolution survey (30m flying height, 50 m line spacing).

	K	U	Th
Standard	12.3	27.1	16.7
NASVD	12.0	17.3	15.7
MNF	12.5	8.3	13.6

The features of the noise reductions methods are

1. there is no improvement in K (and also total count) images by any method over conventional processing,
2.. Th images show some improvement dependant on the level of Th counts, and
3. U images show major decrease in noise with MNF being more effective than NASVD.

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Improved NASVD Smoothing of Airborne Gamma-ray Spectra

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Noise-adjusted singular value decomposition (NASVD) is a spectral component analysis procedure for the removal of noise from gamma-ray spectra (Hovgaard, 1997, and Hovgaard and Grasty, 1997). The procedure transforms observed spectra into orthogonal spectral components. The higher-order components represent the signal in the original observed spectra, and the lower-order components represent uncorrelated noise. Noise is removed from the observed spectra by rejecting noise components and reconstructing smooth spectra from higher-order components.

A synthetic data set has been used to obtain new insights into the NASVD method. The data set is based on an airborne survey over the Jemalong Plains area, NSW. The estimated ground concentrations of K, U and Th were spatially filtered and then used to synthesise airborne spectra using simulated Poisson noise. These spectra include a background component based on typical aircraft and cosmic background and a simple model of the distribution of atmospheric radon. The application of NASVD smoothing to this dataset produces a visually striking reduction in U fractional errors compared with that typically obtained using this method. Careful investigation suggests that the reason for this is that the Jemalong Plains data set exhibits a very high correlation between U and Th, and because the survey was flown on a day of low and near constant atmospheric radon concentration. If the data set is modified by either adding spectra derived from an anomalous U/Th source, or by including atmospheric radon variations typical of most airborne surveys, then the large reductions in U concentration error are no longer achieved.

The synthetic data tests suggest that the smaller the variation in spectral shape within the input signal, the greater the noise reduction. This is used to develop an improved implementation of the NASVD method that can be applied to large survey data sets. Instead of processing the survey data by flight, the entire survey database is sorted into classes on the basis of similarity in spectral shape. The application of the NASVD method to these classes typically halves the K, U and Th fractional errors compared with those obtained when the data are processed by flight. This greatly increases the amount of geological information that can be extracted from enhanced images of the data.

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Case Studies in Principal Component Analysis and Development in Calibration Techniques

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In the last few years, the advent of high speed digital acquisition systems coupled with computer based spectrometers has enabled routine collection of multi-channel spectrometer data. This in turn has facilitated the development of robust multi-channel processing techniques that are used routinely to apply basic corrections and to substantially improve data quality. A detailed example showing the advantages of multi-channel processing is presented using data from a helicopter borne aeromagnetic and radiometric survey flown in south eastern Australia. Derivation of the calibration data required for routine multi-channel processing from pre survey tests is also presented.

Some Thoughts on Multichannel Processing of Airborne Gamma-ray Data

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Both the Maximum Noise Fraction (MNF) and the Noise Adjusted Singular Value Decomposition (NASVD) method of multi channel processing have been shown to be significantly better than the spectral fitting method in reducing the noise in airborne gamma-ray data.

In the spectral fitting procedure, the airborne spectra from potassium, uranium and thorium must be determined either experimentally using calibration pads or theoretically by Monte Carlo methods. However, it is difficult to simulate airborne spectra at energies below about 400-500 keV because a significant fraction of the low energy gamma-rays is downward scattered skyshine radiation. Consequently, the standard spectral fitting procedure cannot normally be used below an energy of about 500 keV. An even higher energy limit may be necessary in the northern hemisphere due to the presence of ^{137}Cs at 662 keV.

The MNF and the NASVD methods do not have these limitation and the analysis can be carried out over all energy ranges. Although there is little spectral information in the low energy part of the spectrum, there is information on overall levels of radioactivity. At a typical survey altitude of 123m approximately 60 percent of the measured counts are below 600 keV.

Another reason why the MNF and NASVD methods achieve better results than the spectral fitting method is because they make use of the strong correlation between potassium, uranium and thorium both in their detector response as well as their occurrence in nature. In the multi-spectral fitting procedure, the potassium, uranium and thorium spectra are treated as independent variables.

The potassium, uranium and thorium gamma-ray spectral shapes are dependent on aircraft altitude as well as on the distribution of radioactivity in the ground and the amount of above ground biomass. Consequently any spectral fitting method must take this into account otherwise the calculated and measured spectra will not fit causing possible biases in the data.

One advantage of the NASVD method over the MNF method is that it does not depend on the ordering of the spectra. Consequently at the boundaries of different rock types, or in flying over single value anomalies, there will be no evidence of spatial filtering and all real features relating to changes in radioactivity will be retained.

Experiences with downward continuation of AGRS data

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A mathematical model for the downward continuation of radiometric data has been available for some years and has been discussed by Gunn (1978) and Craig (1993) in recent times.

The technique, which is a Fourier domain deconvolution of the effects of aircraft altitude, results in data sets which have significantly more geological resolution than conventional airborne radiometric data. This is achieved by modelling and removing blurring effects of atmospheric scattering on gamma rays, overlapping fields of view in successive observation and remoteness of detector from the source.

Up until mid-1997, a limiting factor on the usefulness of such techniques had been the availability of comparatively noise-free data for input into the process. Following the recent successful application of statistical noise filtering to radiometric data, the downward continuation technique has been also successfully applied to radiometric data. We will present before-and-after images to illustrate the technique over a some test areas and discuss the pitfalls in the method.

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Gunn, P. J., 1978, Inversion of airborne radiometric data. Geophysics, 43, 133-142.

Modeling detector response in airborne gamma-ray spectrometry

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The forward model currently used for downward continuation of airborne radiometric data assumes that the detector response is independent of orientation (a "uniform model") and neglects the movement of the aircraft during the integration time. However, airborne crystals are rectangular which causes a directional dependence on the probability of detection. In addition, the aircraft can move a significant distance relative to its height during a single measurement, especially at low altitudes. The detector response at any orientation is a function of three attributes; (i) the solid angle (area) of the detector as seen by the source; (ii) the thickness of the detector in the direction of the source; and (iii) the peak-to-total ratio at the given incidence (proportion of gamma rays recorded at the correct energy). We present a model of the detector that uses simple geometrical arguments to calculate the area and thickness of a rectangular detector at any orientation. Using Monte Carlo simulations, we found that the peak-to-total ratio was only weakly dependent on orientation and therefore assumed it was constant. This "geometrical detector model" showed excellent agreement with experimental data for a single 4.2 litre crystal and Monte Carlo simulations of an airborne survey with a 16.8 litre crystal. Further, the movement of the detector during the integration time can be simply incorporated as it can be expressed as a convolution, which reduces to a multiplication of factors in the Fourier domain.

For a 16.8 litre airborne crystal the geometrical model predicts a significantly higher spatial resolution than the uniform model. For example, at 60 m elevation the 90% contributing area for Potassium is predicted by the geometrical model to be 6.0 ha compared to a prediction of 8.6 ha for the uniform model, a difference of 43%. We discuss the implications of using a stationary, uniform model for downward continuation and recommend; (i) that it be replaced by the geometrical model and (ii) that the movement of the detector during the integration time is incorporated.

Deconvolution of Radiometric Data Using Equivalent Layers

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Gunn (1978) demonstrated, with model data, that, provided no noise is present in the data, accurate deconvolution of airborne gamma-ray spectrometric data can be obtained by applying a Wiener filter. The Wiener filter was obtained by the heuristic approach of obtaining a set of convolution coefficients to convert a known input (a model airborne radiometric anomaly) into a known output (a representation of the radioelement distribution causing the anomaly). The filter coefficients, which were calculated according to optimum least squares design criteria were then applied successfully to situations for other radiometric anomalies recorded at the same elevation as the model anomaly used to calculate the coefficients. The theory of the Wiener filter approach was extended to allow for radiometric data contaminated with noise although a test of this approach was not demonstrated. The Wiener filter approach of using a known input and a known output to design filter coefficients has the advantage that it can allow for factors such as instrument sensitivity and directionality of responses.

The Wiener filter approach however assumes that the deconvolution is a linear process and as such assumes that the sources are on a horizontal surface and the gamma-ray counts are recorded at constant horizontal distance above the horizontal source surface. Gunn and Almond (1997) have introduced the concept of a radiometric equivalent layer which is a surface distribution of radioelement sources which produces identical counts to the counts observed by an airborne detector. The radiometric equivalent layer is similar to the equivalent layer concept used in the processing of gravity and magnetic data and has the advantage that neither the true sources nor the equivalent layer sources need to be on horizontal surfaces and the observed airborne counts need not be observed on horizontal surfaces. Once an equivalent layer of sources is obtained they can be used to recompute countrates at different heights. The equivalent layer can be used to correct observed airborne count rates for irregular ground clearance. The equivalent layer does not have to be calculated on a true physical surface however the equivalent layer on the true ground surface in an area gives a true representation of the radioelement distribution of the area and as such is a deconvolution of the observed airborne counts. Gunn and Almond (1997), using model data, have successfully tested an iterative method of computing radiometric equivalent layers and have used the result to accurately height correct observed airborne counts and compute ground radioelement concentrations.

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Some features of airborne radiometric data processing

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VIRG-Rudgeofizika

1. In the first stage of the processing, we believe it absolutely necessary to analyse the stability of the spectrometer, using spectra recorded over survey lines, as our experience in processing of data even from modern spectrometers of the GR820 type shows that serious problems may take place which are easily solved by using automated algorithms during the data input stage. The application of standard check measurements of signals from button sources does not always allow to notice in-flight errors in the spectrometer performance.

2. To calculate compton correction coefficients measurements over ore models are taken. In Russia, the measurements are made on standard small models included in the factory set of the instrument for which correcting multipliers for channels are known, allowing to convert from model spectra to those of radiating half-space in the range from 0.45 to 3 MeV. To determine those correction coefficients special ground measurements of spectra were made over long natural sites practically with the monoelement nature. The technology accepted in Canada and Australia uses large aerodrome or transportable models. The spectrum shape depends on the size of the model as the intensity ratio of the direct and scattered radiation depends the radiating target. In case of the measurements with transportable models, the spectra can be conditionally considered saturated for the energy ranges greater than 1 MeV. This is quite enough, if the aim of the measurements is determination of concentrations in equi-weighted uranium, thorium and potassium, using 3 energy windows of the spectrum. The procedure for the determination of compton correction coefficients used in Russia allowed extension of radiometric method capabilities. First of all, radiometric surveys are meant, with a view to determine areas contaminated with falls of radioactive cesium-137 from 0.667 MeV peak after accidents at atomic electric stations and explosions. Here, using a survey procedure practically similar to

a standard geological survey, we managed to accurately determine the contamination level, starting from practically clean areas with the contamination level adequate to the global one to high levels hundred times greater than the global contamination. We do not know how the problem of environment surveys is urgent for Australia but perhaps significant experience we gained will be of interest for you. We used the same procedure for detection of areas where radioactive equilibrium had been disturbed in the uranium-radium series from the protactinium-234 peak at 1.01 MeV. For those areas, the concentration of uranium in rocks, according to chemical analysis, exceeds much the concentration determined by gammaspectral method, since this method determines the concentration of uranium from the bismuth-214 peak, assuming that radioactive equilibrium exists in the uranium-radium series. This procedure allows obtaining of new data for geological interpretation of processes that take place in rocks.

3. In practice, situations often occur when application of a simple exponential algorithm for height attenuation correction leads to unsatisfactory results. Usually, in those cases, to eliminate obvious errors algorithms for tying-in are used. This outwardly improves the result but in this case, part of the information gets lost. In case recorded radar altimeter readings differ from the nominal survey altitude for more than 30-40 m, it usually evidences that the relief is not flat. With this, due to a number of reasons, doubts arise as to the validity of application of the simple exponential law. First of all, the theoretical considerations lead to corrections in the law of height attenuation itself but for a correct application of formulas at least correct initial data are required. In this case, the radar altimeter readings do not correspond to the real distance to the centre of the detector field of view. For instance, in draped survey flights, the recorded radar altimeter readings may differ significantly and differently from the true survey flight for lines covered "up hills" and "down hills" and that difference will depend on too many specific factors, for instance, on the type of the carrier, wind speed, steepness of the slope etc. Under those conditions, it is unreasonable to seek for a general theoretical approach to the solution of the problem. Here, a purely empirical approach proves to be efficient which in some cases allowed us to obtain results useful for further interpretation. The method we use comes to the determination of effective factors of the height attenuation directly from the measurements over the survey area and we manage to partially compensate radar altimeter data unuseful in this case.

'Compton Counting' and Noise Reduction

Ed Reeves
Tesla 10

'Compton Counting' is a new method developed for the processing of airborne radiometric data using most or all of 256 available channels, which combines some elements of the noise reduction capabilities of some of the methodologies developed within the last few years, with direct processing, avoiding most of the conventional suite of processing coefficients. The title 'Compton Counting' alludes to the powerful constraint effect provided by the Compton continuum in methods such as this.

The method is similar to at least one other currently available method, in that radio-element spectra, varying with flying height, are used to derive equivalent principal window counts or apparent concentrations, by least squares.

The novelty of this method lies in the extraction of the radio-element spectra, and their vertical derivatives, from the data set itself, the philosophy being that any idiosyncrasies in aircraft, equipment, terrain or whatever are automatically resolved. The extraction includes separate Uranium and Radon spectra as well as Potassium, Thorium and combined aircraft/cosmic background spectra, and the height derivatives of all of these.

By far the greatest difficulty in the spectral extraction is the separation of Uranium and Radon spectra, because of their intrinsic similarity and because of the (usually) low Uranium count. Counterbalanced against this is the sharp contrast in their spatial distribution, and this contrast is used to effect the separation.

The implementation of 'Compton Counting' is a full graphics implementation for workstations, still under development in part. Preliminary results are presented.

Along with 'Compton Counting', an implementation of the spectral component analysis technique, developed by Hovgaard and Grasty (1997), has been made. The implementation differs in a few important respects from that made publicly available by Exploranium; firstly, an entire data set or representative subset is used to derive the set of basis vectors, ensuring uniform application of the noise reduction; secondly, the basis vectors can be applied to other data sets, particularly useful for small surveys. This is a full graphics implementation for workstations, so that all aspects of the process can be viewed on the screen, at process time or on replay.

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